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Assessment of Stain and Decay in Paper Birch, Point Mackenzie, Alaska: An Interim Report

Biological Evaluation R10-TP-106
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INTRODUCTION

Paper birch (*Betula papyrifera*) forests comprise more than 2/3 of the total forest land, growing stock volume, and sawtimber volume in the Matanuska-Susitna (Mat-Su) Valley, south-central Alaska (Setzer et al. 1984, U.S. Department of Agriculture, Soil Conservation Service 1986). Assessments of birch defect have been limited to the development of cull factors. A fall-buck-and-scale study of birch in the Susitna River Basin indicated that 36% of the gross sawtimber (>11 inches diameter) volume and 19% of the gross pole timber volume was cull (U.S. Department of Agriculture, Soil Conservation Service 1986). Interest in utilizing the birch resource for products other than firewood is growing. Defect, such as stain or decay, limits the use of birch by reducing the volume and quality of solid wood products. While cull factors provide managers with volume loss information, little knowledge is available on the patterns and causes of stain and decay in paper birch. Knowledge of these patterns would provide key information for assessing the paper birch resource and potential product utilization.

Limited information is available on the occurrence and impact of diseases of paper birch. Surveys in Alaska have identified a variety of canker, heart rot, and root rot fungi that infect birch (Kimmey and Stevenson 1957, Volk et al. 1994). However, no attempt was made in the fungal surveys to assess the impact of the disease-causing organisms on the birch resource. Early forest surveys in the Cook Inlet area indicate a high incidence of stain in paper birch larger than eight inches diameter (Drake 1923). The reddish brown stain develops in the central column of living birch trees. Information on the incidence and patterns of this stain is lacking.

A dissection study of 600 paper birch trees on the Kenai Peninsula, Mat-Su Valley, and Interior Alaska was conducted by USDA Forest Service, State and Private Forestry personnel from 1997-2000. The purpose of the study was to determine the extent, patterns, and causes of stain and decay in even-aged unmanaged paper birch stands in mature (60-80 years) and older (>120 years) age classes. This study also investigated whether site factors, age-class, and regional location affect pathogen incidence and severity, the presence of decay indicators, and associated decay columns.

To assist with the study, the Mat-Su Borough granted permission for operations to be conducted near Point Mackenzie in two older paper birch stands (>120 years). This report is an assessment of the stain and decay patterns for 20 trees within the two Point Mackenzie stands. A report of the full study will be prepared at a later date.

METHODS

Two 1/5th acre plots were randomly established in paper birch stands on Mat-Su Borough land near Point Mackenzie. One plot was in the Lake Lorraine area (LL1), and the second plot was located in Forest Management Unit #13 (FMU13). Stands were selected in these areas because they were even-aged, >120 years, accessible by the road system, and were comprised of at least 50% paper birch in the overstory.

Site factors collected on each plot included elevation (ft.), aspect, slope (%), soil drainage, and a tally of tree species and understory vegetation. Within each plot, ten paper birch trees were randomly selected for destructive sampling. Tree data collected included diameter at breast height (DBH) (in.), height (ft.), height to live crown (ft.), height to a 4 and 6" diameter top (ft.), and assessments of external stain and decay indicators. Nineteen indicator codes were used, nine codes related to pathogens (identification of conks or mushrooms). Ten codes related to injuries such as frost cracks, broken branches (>0.5 inches), trunk or basal wounds, and broken tops (Hiratsuka et al. 1990). Each tree was re-assessed for indicators after felling.

Tree boles were dissected at 8 ft. intervals above a 1 ft. stump. Two cross-sectional measurements, at right angles, were taken at the butt and top end of each bole section. If stain or decay was encountered, additional cuts traced the stain or decay column length and determined, if possible, its origin. Polaroid photographs were taken of the defective sections (Hennon and DeMars 1997) and the areas of stain and decay were digitized from the photographs using an AutoCAD program. Gross and net cubic foot tree volumes were calculated for trees to a 4" top using Smalian's formula (Society of American Foresters 1955).

The two Point Mackenzie sites chosen for study were intended to be replicates within the same geographic area, stand structure, and age class. Since these sites were not "treatments", and data did not appear to be substantially different between the two plots, most of the summary data were pooled and averaged for the two sites.

Site Description

Most of the birch stands within the Susitna River Basin are classified as sawtimber (U.S. Department of Agriculture, Soil Conservation Service 1986) and the two Point Mackensie stands also fall into this category. Paper birch was the only canopy level tree in both stands. The stands were old (>120 years), even-aged and relatively open with 75 to 90 birch/ac on mesic upland sites. Stain and decay, however, prevented an accurate ring count for actual tree ages. Elevation of the stands was 200 feet, with slopes less than 15%.

Dead standing trees and birch with broken boles were present, scattered throughout the stands. Spruce saplings, 50 trees/ac (all spruce < 4" DBH, < 10 ft. height), occurred in LL1. Spruce seedlings and saplings were absent in FMU13, but may be present in other areas of the stand that were not sampled.

As with most upland sites within the Basin with thin organic mats (< 4"), the natural fertility of the stands was likely low (U.S. Department of Agriculture, Soil Conservation Service 1986). Bluejoint grass (*Calamagrostis canadensis*) occurred at low to moderate levels in both plots. Other common understory plants included common horsetail (*Equisetum arvense*) and bunchberry (*Cornus canadensis*). Various other shrubs and herbs occurred on the plots, but canopy covers did not exceed 15% of the ground cover.

RESULTS AND DISCUSSION

In both plots, tree stature was similar and merchantable tree length exceeded 40 feet (Table 1). All trees had measurable defect from stain or decay; only 10% of the trees lacked decay in either plot.

Table 1. Summary of general tree measures in two plots in the Mat-Su Valley.

Plot	DBH (in)	Total height (ft)	Height to live crown (ft)	Height to a 4" top (ft)	Trees with stain (%)	Trees with decay (%)
LL1	12 (0.7)*	55 (2.2)	22 (3.3)	42 (2.8)	100	90
FMU13	11 (0.6)	58 (2.1)	25 (2.0)	47 (1.9)	100	90

* Means followed by standard error in parentheses.

Overall, the gross and net volumes were similar for the two plots (Table 2). The high proportion of stain and decay defect, an average of 36% for the two plots, substantiates the 36% cull factor for sawtimber developed from a fall-buck-and-scale study of birch in the Susitna River Basin (U.S. Department of Agriculture, Soil Conservation Service 1986). However, a substantial difference occurred in the proportion and volume of stain and decay measured in each plot (Table 3). In FMU13, extensive portions of the red heart stain columns were invaded by wood decay fungi. This resulted in a lower volume of defect due to stain and a higher volume due to decay in FMU13 as compared to that in LL1. Since the process of stain and decay is a continuum of events that varies among trees and sites, differences in the amount of stain and decay in each plot was not unexpected.

Table 2. Summary of gross and net volumes for paper birch in two plots in the Mat-Su Valley.

Plot	Gross volume (ft^3)	Net volume (ft^3)	Average defect (stain + decay) (%)
LL1	18.3 (2.3)*	12.4 (1.9)	33 (4.3)
FMU13	20.3 (3.0)	12.6 (2.1)	38 (8.1)

* Means followed by standard error in parentheses.

Table 3. Measures of stain and decay for paper birch in two plots in the Mat-Su Valley.

Plot	Stain defect (%)	Decay defect (%)	Red heart stain volume (ft^3)	Decay volume (ft^3)	Red heart stain column length (ft)	Decay column length (ft)
LL1	25 (4.3)*	8 (2.8)	4.3 (0.6)	1.6 (0.7)	47 (1.9)	17 (3.5)
FMU13	7 (2.2)	31 (8.2)	1.4 (0.6)	6.1 (1.9)	30 (6.2)	29 (5.1)

* Means followed by standard error in parentheses.

Sites for the development of Stain and Decay

Stem injuries and defects, averaging 10/tree in both plots, included broken branches, broken tops, trunk and basal wounds, frost cracks, conks/mushrooms, and burls (Table 4). Broken branches were the most frequently encountered stem injury, accounting for nearly 2/3 of all stem injuries in both plots. Location of the injuries and defects was variable. Burls and basal wounds

Table 4. Description of stem injuries and defects of paper birch.

Injury or defect	Average* Incidence (% trees)	Average* Dimensions	Description of location on bole
Injuries:			
Broken branch	100	1.5 inches diameter	Throughout stem, primarily above 16 ft.
Broken top	70	< 4" diameter	Above but within 4 ft. of the 4" merchantable top
Trunk wound	60	0.8 ft^2; age = 28 yr	Throughout stem, less than half were visible within the first 16 ft.
Basal wound	40	1.2 ft^2; age = 49 yr	Base of tree
Frost crack	40	5.0 ft. length; most closed and calloused	Throughout stem, most were visible within the first 16 ft.
Defects:			
Conks/ Mushrooms	50	Variable, depends on decay fungus	Throughout stem, approximately half were visible within the first 16 ft.
Burl	30	0.3 ft^2	Consistently present in first 16 ft.

* Data pooled for both plots due to small sample sizes and low variability between plots.

consistently occurred within the first 16 ft. Many other injuries and defects occurred throughout the stem and within the live crown where branches or foliage may partly obscure their visibility. Careful assessments of trees will be needed to ensure that injuries and defects are noted.

All stem injuries and conks/mushrooms were sites that consistently developed defect (Table 5). Most burls, globe-like woody swellings, had clear wood and lacked defect. All conks/mushrooms and three types of injuries, broken tops, basal wounds, and trunk wounds (>1 ft^2), were highly associated with decay. The process of decay development is dependent on many factors including injury location, size and season of injury, age, and decay organisms that invade the site. Thus, the association of decay with fungal fruiting bodies, large trunk wounds,

Table 5. Association of stain and decay with injuries and defects of paper birch.

Injury/defect	Association with defect [1, 2] (stain or decay)	Association with decay only[1]	Average[2] decay column length or description	Decay volume[2] (ft^3)
Injuries:				
Broken branch	High	Moderate	Generally less than 1 ft above or below branch, primarily confined to the dimensions of the imbedded branch	*
Broken top	High	High	3.5 ft.	0.16
Trunk wound	High, stain only if <15 yr	Mod. if < 1 ft^2 High if >1 ft^2	1.7 ft above wound, 2.8 ft below wound	0.25
Basal wound	High	High	*	*
Frost crack	High	Moderate	*, decay extended at least the length of the frost crack	*
Defects:				
Conks/ Mushrooms	High	High	Variable, depends on decay fungus (Table 6)	Variable (Table 6)
Burl	Low	Low	*	*

[1] Injuries or defects were classified at three levels for association with stain or decay: High = =75%, Moderate = 35 to 74%, Low = =34%.

[2] Data were pooled for both plots due to small sample sizes and low variability.

* Decay column length or volume was not possible to determine or isolate to the injury site.

and injuries at the top and base of the tree was not unexpected. Other injuries had a moderate association with decay. Decay columns were generally greater below than above the injury or

defect. Measures of decay will vary depending on the wood decay fungus that invades the wound. Since most trees had multiple merging stain and decay columns, isolating the decay columns or volumes to the injury site was often not possible (Table 5).

Patterns and Causes of Stain

Two types of stain were noted in the sapwood of trees on both plots; a red heart stain in the central core and, a stain in the outermost sapwood (Figs. 1, 2). The red heart stain was the predominant stain, occurring in all trees in both plots and accounting for an average of 95% of the stain defect volume in both plots. Extensive columns of red heart stain occurred in both plots (Table 3). The second stain was a minor defect, present in an average of 15% of the trees in both plots.

Birch wood, normally creamy white, frequently develops a reddish brown discoloration, called red heart (Campbell and Davidson 1941, Shigo 1965, Shigo and Larson 1969) (Fig. 1). The red heart stain is a common defect of living paper birch throughout the range of this tree in North America and can be locally severe (Peterson et al. 1997, Siegle 1967). The discolored wood is sharply delimited and has a higher moisture content than the surrounding sapwood. Stained wood does not appear to be affected as to strength or hardness, but tends to check and crack on drying more than the surrounding sapwood (Campbell and Davidson 1941).

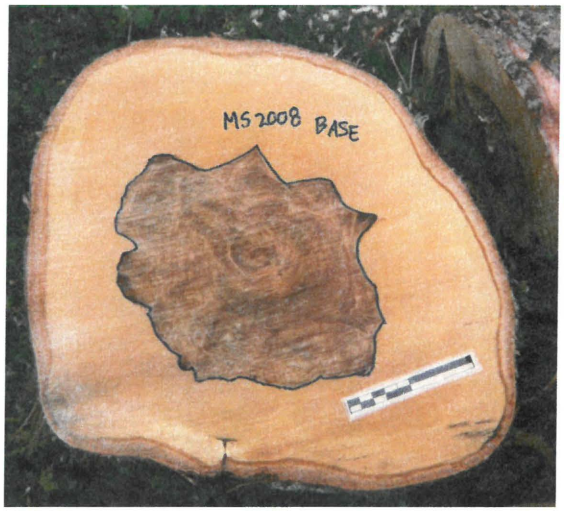

Figure 1. Red heart stain.

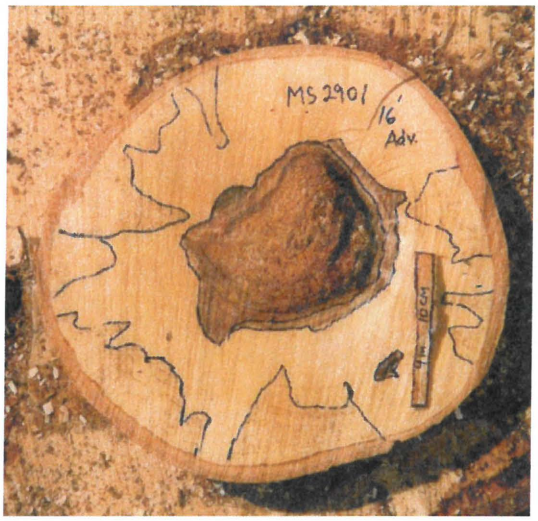

Figure 2. Wedge-shaped unknown stain of the outermost sapwood.

The discoloration process is initiated by an injury to the tree, such as stem and roots wounds, frost cracks, and broken branches (Shigo and Larson 1969). The tree responds to the injury by producing phenolic compounds at the site of the injury. Oxidation of the phenols results in a reddish-brown discoloration that extends more rapidly longitudinally than radially. The oxidation

process is likely catalyzed by bacteria and non-decay fungi that invade the injured site and produce phenol oxidases (Siegle 1967). The stained wood then undergoes changes in pH and moisture content. At this stage, the stained wood is called red heart. Although discolored, the wood is not decayed at this point. Wood decay fungi may invade injuries and cause decay within and beyond the red heart stain columns.

Extensive columns of red heart stain can develop vertically in a tree (Table 3). New growth rings act as a "barrier" to discoloration, as the discoloration seldom moves into the new cells (Shigo and Larson 1969). Thus, new wood that forms after the injury is generally not discolored unless further injury occurs. The extent of red heart stain depends primarily on tree vigor and severity of the wound (Shigo and Larson 1969). With the exception of root wounds, red heart columns were more extensive below an injury than above.

All of the trees on both plots had red heart stain and also had numerous stem injuries, including broken branches and tops, wounds, and frost cracks that occurred from the base to a merchantable top. Since red heart stain is initiated by injuries, the continuous and extensive red heart stain columns detected on both plots is not surprising (Table 3).

The second stain type was not commonly encountered, occurring in only 3 trees in both plots. The stain appeared as longitudinal streaks between the annual rings that occurred in triangular wedges in the outermost sapwood (Fig. 2). The cause of the stain was unknown but may have developed in response to bending of the stem and thus, tension or compression at the point of bending. The presence of this stain was not associated with injuries. Stain columns were relatively long, averaging 20 ft. in both plots. However, only a small portion of the merchantable volume in those trees was affected, average volume defect = 0.6 ft^3 in both plots, as compared to defect associated with red heart (Table 3).

Patterns and Causes of Decay

Ninety percent of the trees in both plots had measurable decay from root and stem decay fungi. Multiple decay columns and decay agents occurred in nearly all the trees in both plots. Six wood decay fungi and a canker fungus were identified on the plots (Table 6). Descriptions and illustrations can be found in the book Insects and Diseases of Alaskan Forests (Holsten et al. 2001).

Table 6. Pathogens of paper birch in two Point Mackensie plots, south-central Alaska.

Pathogen	Type of defect	Average[1] incidence (% trees)	General Location	Average[1] length of decay column	Decay volume[1] (ft^3)
Armillaria sp.	Root rot and decay of lower bole	70	Within first 8 ft of lower bole	5	0.5
Phellinus igniarius	Stem decay	35	Throughout stem	28	6.5
Inonotus obliquus	Stem decay	45	Throughout stem, often in upper bole	11.5	1.9
Fomes fomentarius	Stem decay	10	Upper bole	8	0.4
Pholiota sp.	Stem decay	5	Throughout stem	8	0.1
Piptoporous betulinus	Stem decay	5	Upper bole	5	0.1
Nectria galligena	Canker	5	Throughout stem	3.3[2]	0.3[2]
Unknown	Stem decay	30	Throughout stem, often in upper bole	3.7	0.2

[1] Data were pooled for both plots due to small sample sizes and low variability between plots.
[2] Decay was associated with less than 1/3 of *Nectria* cankers.

The most substantial decay losses were attributable to the three most commonly encountered wood decay fungi, *Armillaria* sp., *Phellinus igniarius*, and *Inonotus obliquus* (Table 6). Other decay fungi, including unknown decay organisms, caused minor decay losses. A low incidence of decay was associated with cankers caused by *Nectria galligena*, as less than 1/3 of the cankers were associated with decay. Most cankers had a thin rind of stain directly behind the canker, penetrating less than one inch into the sapwood. While low levels of decay were associated with the cankers, the stem is weakened at canker sites, increasing the susceptible to bole breakage.

Armillaria root rot, likely caused by either *A. sinapina* or *A. ostoyae*, was the most common decay fungus encountered (Table 6). Both species of *Armillaria* are considered weak parasites, infecting live trees under stress. Since *Armillaria* sp. is primarily spread by root contacts, the high proportion of infected trees within the plots is not surprising. Because decay from this pathogen occurs in the butt log where the volume and value of wood is highest, losses from this organism can be substantial. Decay from *Armillaria* sp. was essentially "hidden" because it could not be detected by external signs and symptoms. Mushrooms of this fungus were not

present on any of the plots at the time of felling and presence of the decay was not consistently associated with external injuries, including basal wounds. *Phellinus igniarius* developed the most substantial decay columns and accounted for the greatest volume loss in both plots (Table 6).

All of the trees with visible fruiting bodies from the decay fungi had advanced decay. Perennial conks produced by *P. igniarius* and *I. obliquus* were the most common and conspicuous, developing on nearly 75% and 50% of trees invaded by these fungi, respectively. Most conks from *P. igniarius* and *I. obliquus* were visible below the live crown. For *P. igniarius* conks, decay columns in both plots averaged 26 ft. above the highest and 4 ft. below the lowest conk. For *I. obliquus*, decay columns averaged 14 ft. above the highest conk and 10 ft. below the lowest conk. Few fruiting bodies from the other decay fungi (Table 6) developed on infected trees.

SUMMARY

Birch trees in the two Point Mackenzie plots had high levels of stain and decay defect, approximately 1/3 of their gross volume. This finding concurs with the 36% cull factor for sawtimber developed from a fall-buck-and-scale study of birch in the Susitna River Basin (U.S. Department of Agriculture, Soil Conservation Service 1986). Since paper birch is short-lived, thin barked, and easily wounded, high levels of stain and decay were expected in this age class. Stem injuries are apparently sites of stain development and invasion by wood decay fungi. However, the proportion of defect specifically attributable to stain or decay will vary among trees and stands.

The primary causes of stain and decay defect of paper birch in the Point Mackensie plots were identified. A condition known as red heart was the primary cause of stain. Columns of red heart stain, often extensive, occurred in all trees. The most substantial decay losses were attributable to the three most commonly encountered wood decay fungi, *Armillaria* sp., *Phellinus igniarius*, and *Inonotus obliquus*. A high level of decay in the butt log was primarily caused by *Armillaria* sp.; decay from *P. igniarius*, and *I. obliquus* occurred throughout the stem. Other decay fungi caused minor volume losses.

All stem injuries were reliable indicators of defect; however, only conks/mushrooms and three types of injuries, broken tops, basal wounds, and trunk wounds >1 ft^2, were highly associated with decay. Thus, although defect (stain and/or decay) can be reliable predicted by stem injuries, decay is more challenging to predict. The variable level of decay associated with most injuries may be due to the low sample size (20 trees) and/or other factors that influence the decay process, such as injury location and size, age, and season of injury. Low levels of stain and decay were associated with burls. Thus, burls are not considered reliable indicators of stain or decay.

The proportion of decayed wood in the two surveyed stands is expected to increase in the future as decay fungi, already established in most trees, continue to decompose wood. Net annual growth rates appear low, thus, these stands are likely losing net wood volume annually. Other stands in this age class in the Point Mackenzie area are expected to have similar high levels of

total defect. If maximizing the wood volume from paper birch stands is desired, managers may need to consider utilizing younger age classes that support lower levels of defect. Defect, such as stain or decay, limits the use of birch. Decay reduces the amount of volume recovered, while stain tends to decrease lumber grade. Stained wood, however, may be usable in some applications including veneer, furniture stock, custom woodworking, and pallet stock. Assessments of the complete data set for paper birch, of which this study is a subset, will help clarify the levels of stain and decay defect across age classes and regions in south-central and interior Alaska.

The paper birch stands in this study appear to have originated following a catastrophic disturbance, likely fire. Paper birch is a pioneer species that readily invades disturbed sites. Later successional tree species, such as white spruce, may establish within birch stands and eventually replace the birch. Succession within the Point Mackensie stands, however, is less clear. Bole breakage and uprooting of birch from heart and root rot fungi are readily apparent and will continue as the stands age. The modest level of spruce saplings and the presence of bluejoint grass suggest that these stands may convert to a grass-dominated site with widely scattered spruce.

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